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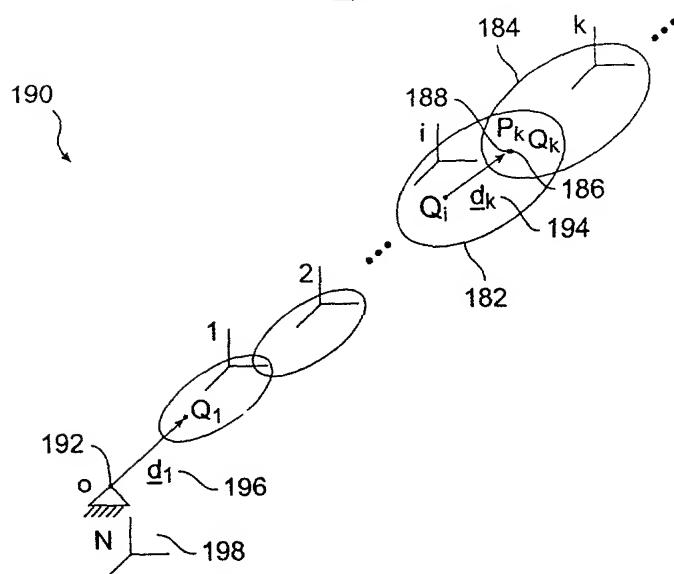


FIG. 3

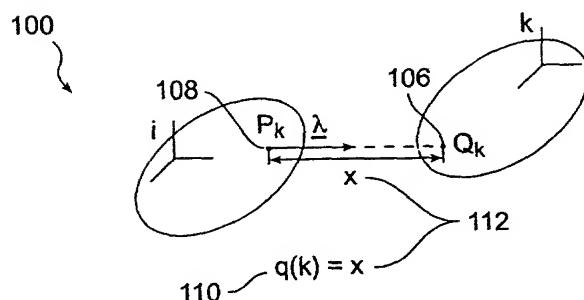


FIG. 4A

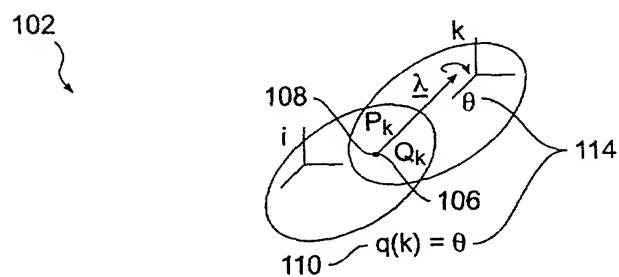


FIG. 4B

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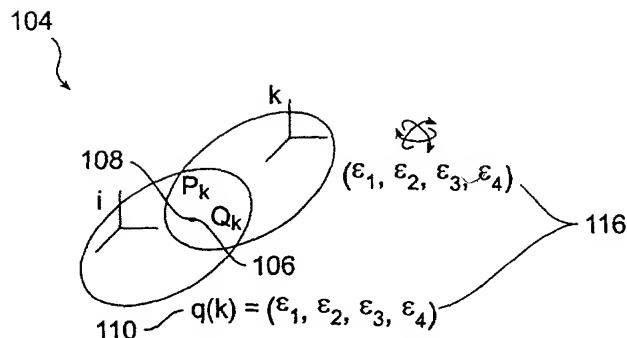


FIG. 4C

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RESIDUAL FORM METHOD TO COMPUTE ρ_q AND ρ_u	DIRECT FORM METHOD TO COMPUTE \dot{q} AND \dot{u}
<ol style="list-style-type: none"> 1. COMPUTE THE FIRST KINEMATICS CALC. AND THE FIRST KINEMATIC RESIDUAL $\rho_q(k)$ 2. GENERATE $\hat{T}(k)$, THE SPATIAL LOAD BALANCE FOR EACH BODY 3. COMPUTE DYNAMIC RESIDUAL $\rho_u(k)$ 	<ol style="list-style-type: none"> 1. COMPUTE \dot{q} USING JOINT SPECIFIC ROUTINES 2. PERFORM FIRST KINEMATICS CALC. WITH $\dot{u} = 0$ 3. GENERATE RESIDUALS ρ_u AND NEGATE $\rho_u = -\rho_u$ 4. PERFORM SECOND KINEMATICS CALC. 5. COMPUTE \dot{u} USING FORWARD DYNAMICS

COMPARISON OF METHODS

FIG. 5

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ANALYTIC JACOBIAN METHOD

1. COMPUTE THE ANALYTIC JACOBIANS OF THE KINEMATICS ROUTINES:

$$J_{qq} = \frac{\partial (Wu)}{\partial q} \text{ AND } J_{qu} = W$$

2. COMPUTE $z \triangleq -M^{-1}p_u(q, u, 0)$ USING THE DIRECT METHOD

3. COMPUTE THE ANALYTIC JACOBIANS OF THE DYNAMICS RESIDUAL ROUTINE

$$\frac{\partial}{\partial q} p_u(q, u, z) \text{ AND } \frac{\partial}{\partial u} p_u(q, u, z)$$

4. BACKSOLVE FOR THE ANALYTIC JACOBIAN OF THE DYNAMICS ROUTINE USING RESULTS FOR z FROM THE SECOND KINEMATICS STEP:

$$J_{uq} = \frac{\partial \dot{u}}{\partial q} = -M^{-1} \frac{\partial p_u(q, u, z)}{\partial q} \text{ AND } J_{uu} = \frac{\partial \dot{u}}{\partial u} = -M^{-1} \frac{\partial p_u(q, u, z)}{\partial u}$$

FIG. 6

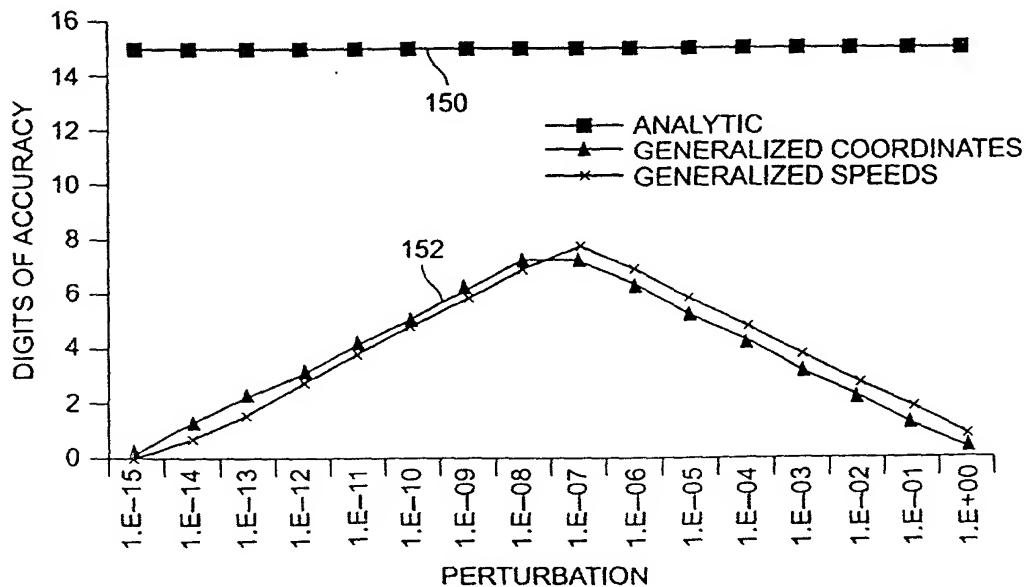


FIG. 7